ADVANCED REACTOR SAFEGUARDS

Dynamic Risk-Based Physical Security Modeling

Physical Security Timeline Analysis in Support of Advanced Reactor Demonstration and Deployment

INL/MIS-23-71855

PRESENTED BY

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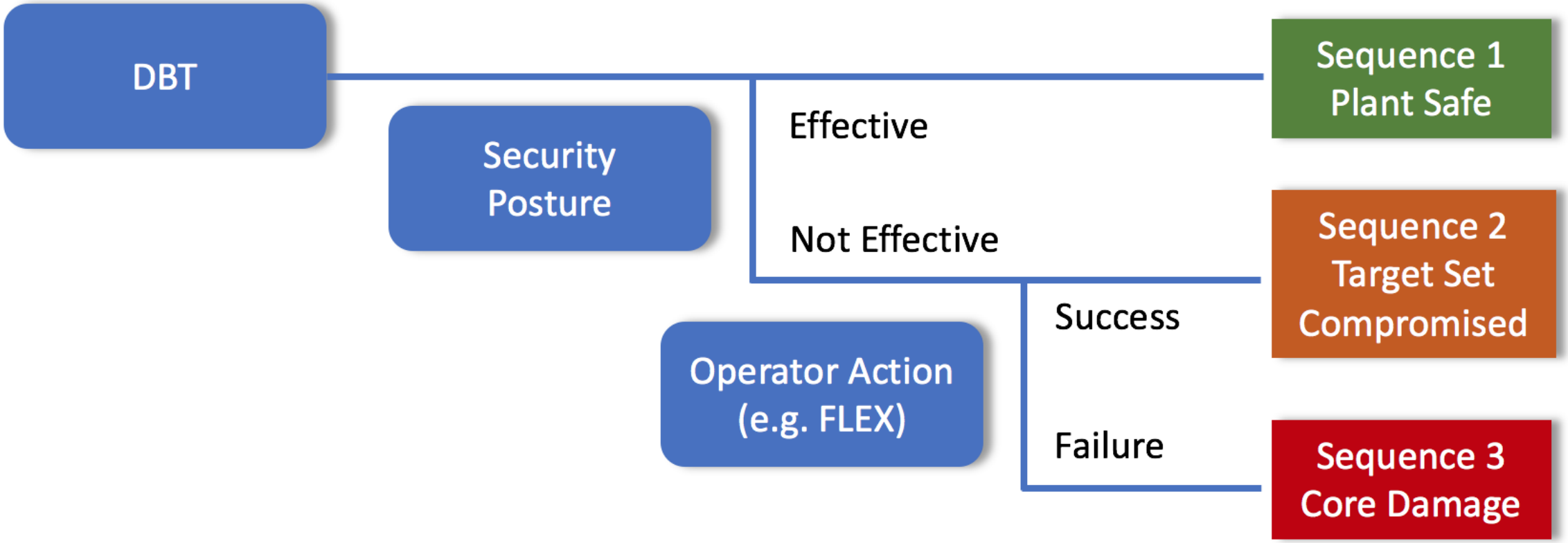
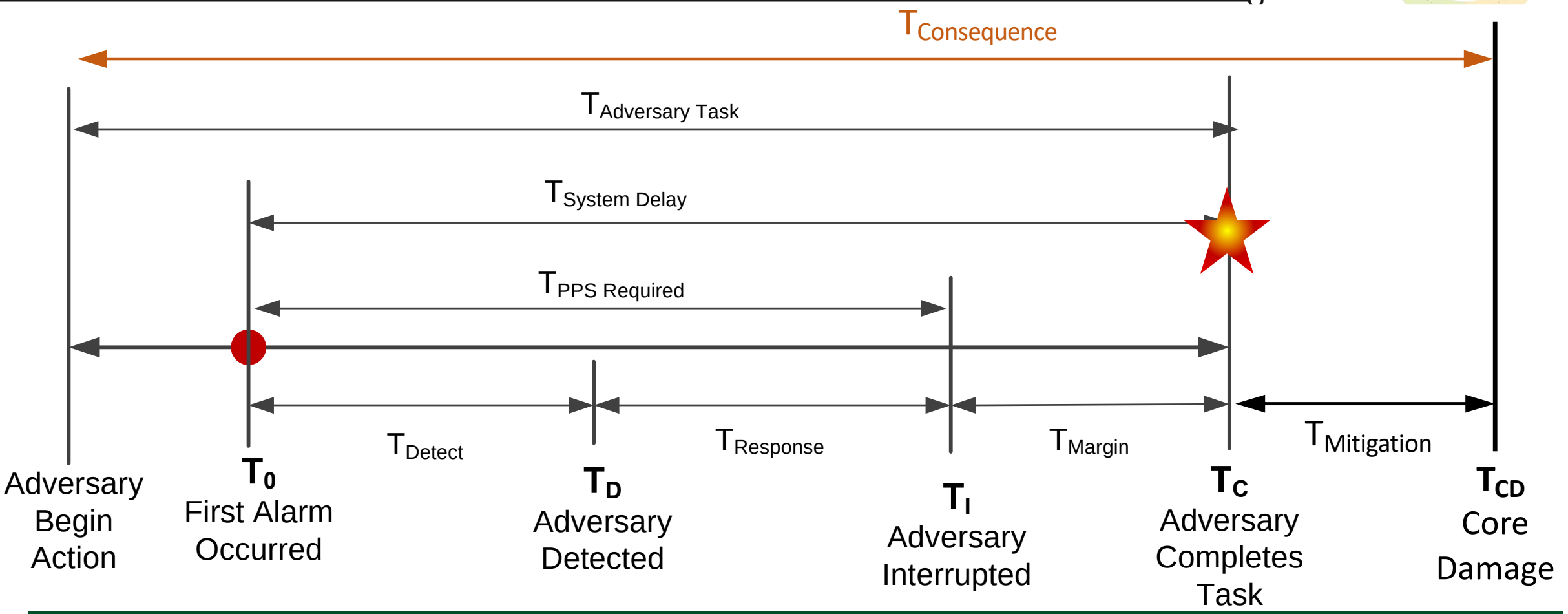
INL Idaho National Laboratory | U.S. DEPARTMENT OF ENERGY

Risk-informed Consequence-based Security



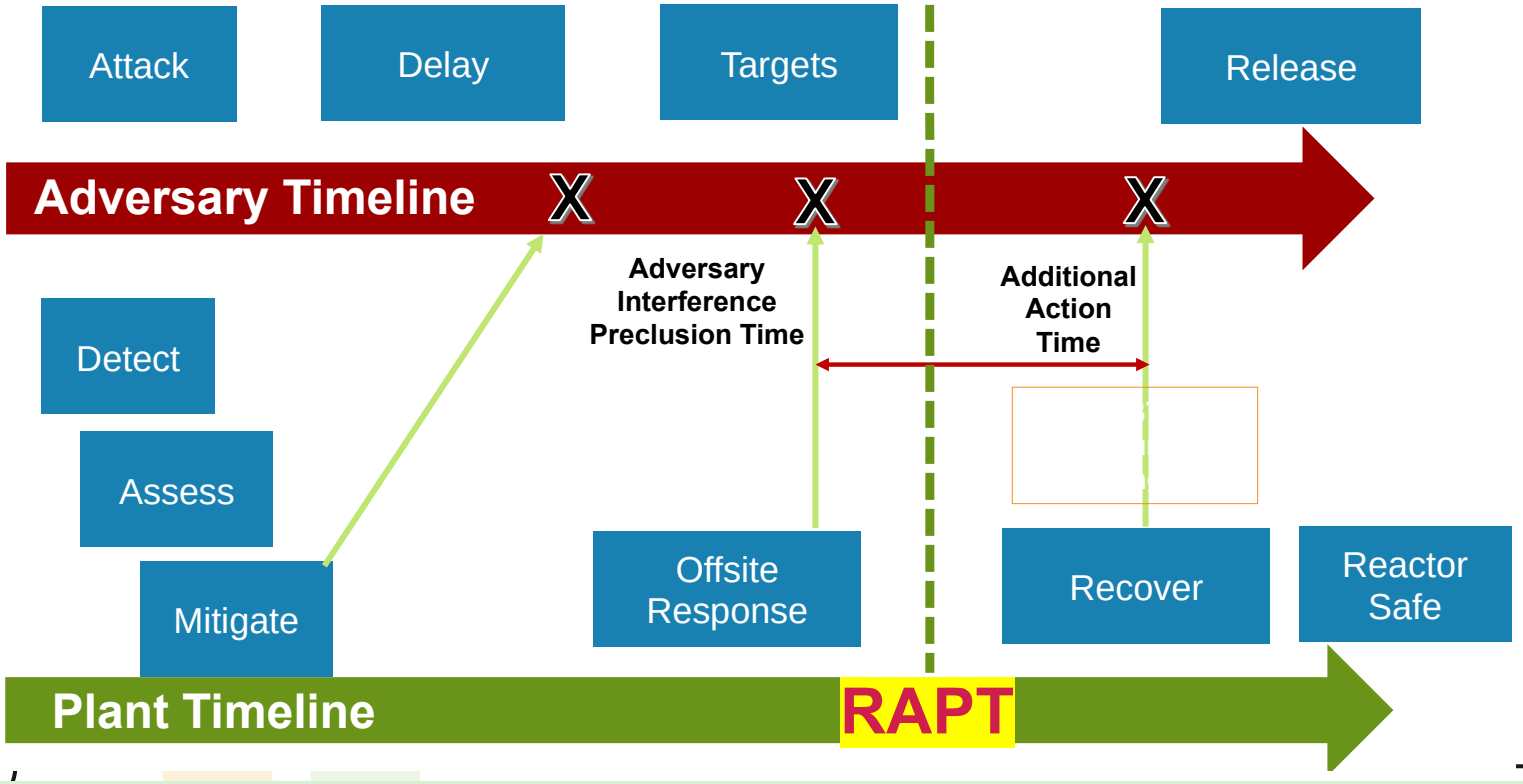
Risk-informed Consequence-based Security



Security Analysis Timeline: Consequence-based Assessment

Risk-informed Consequence-based Regulation

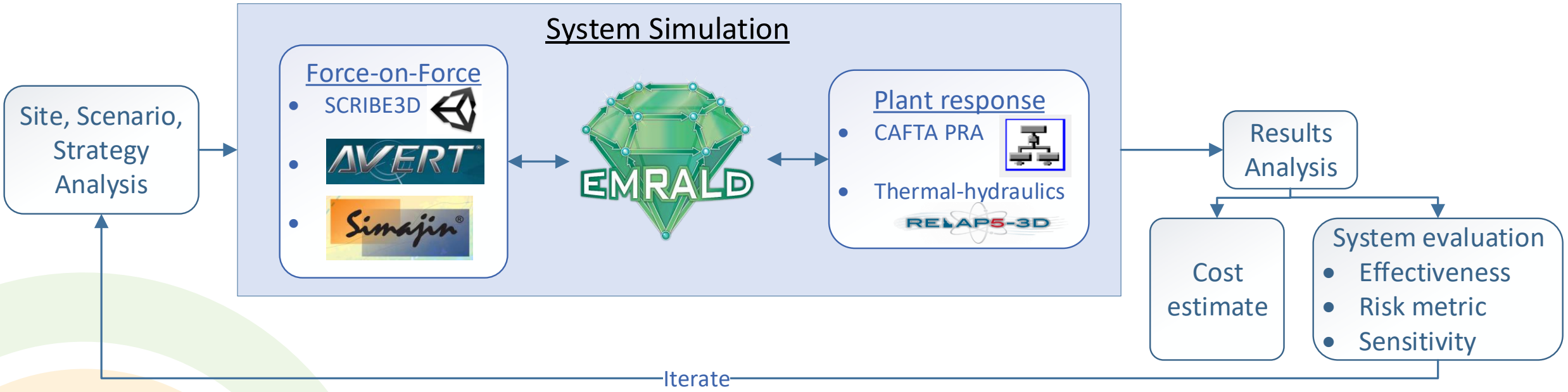
- RAPT: Reasonable Assurance of Protection Time
  - A concept that considers the many existing layers of protection that would provide reasonable assurance that the licensee can independently defend against the DBT
  - Licensee can better focus on protecting more risk-significant target set elements
  - Ability to take credit for operator actions that could be performed after the RAPT



Need stakeholder consensus on acceptable methodology to estimate SBT

SECY-20-0070: Technical Evaluation of the Security Bounding Time Concept for Operating Nuclear Power Plants

Dynamic Framework



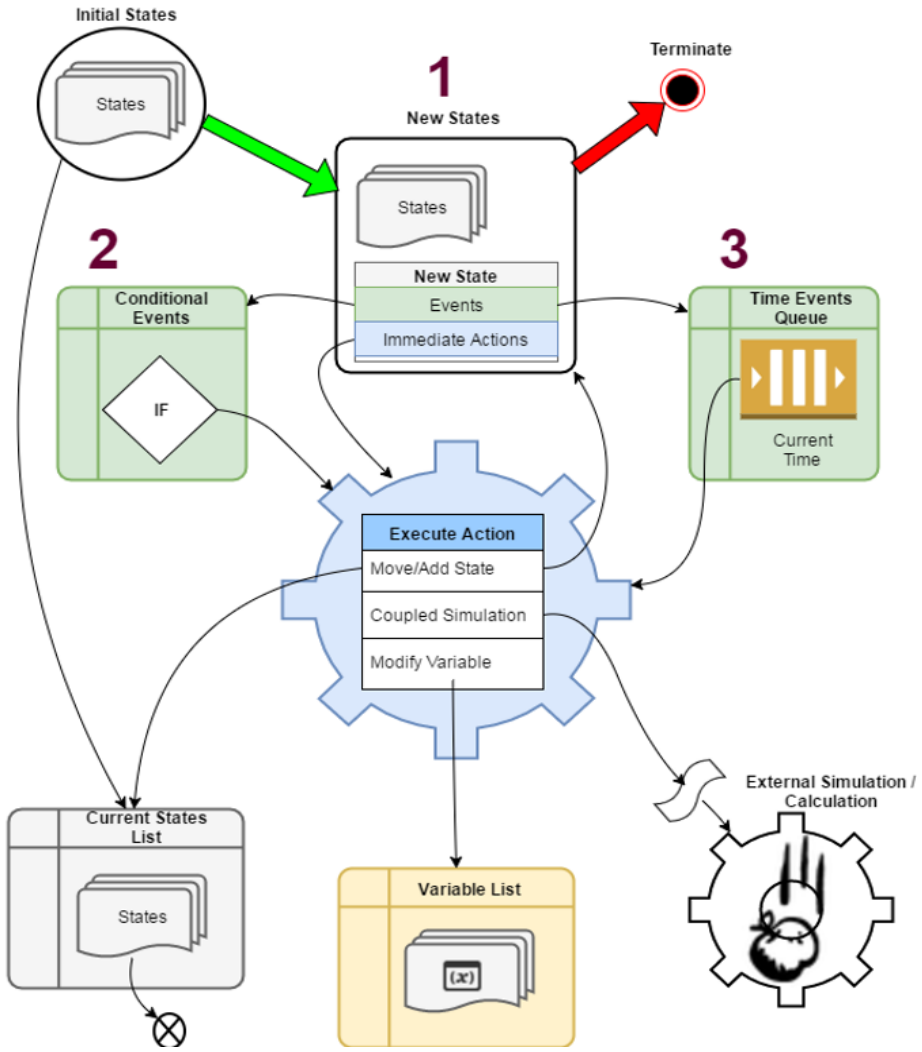
Dynamic Framework

Upon loading, initial start states are added to the “Current” and “New States” list.

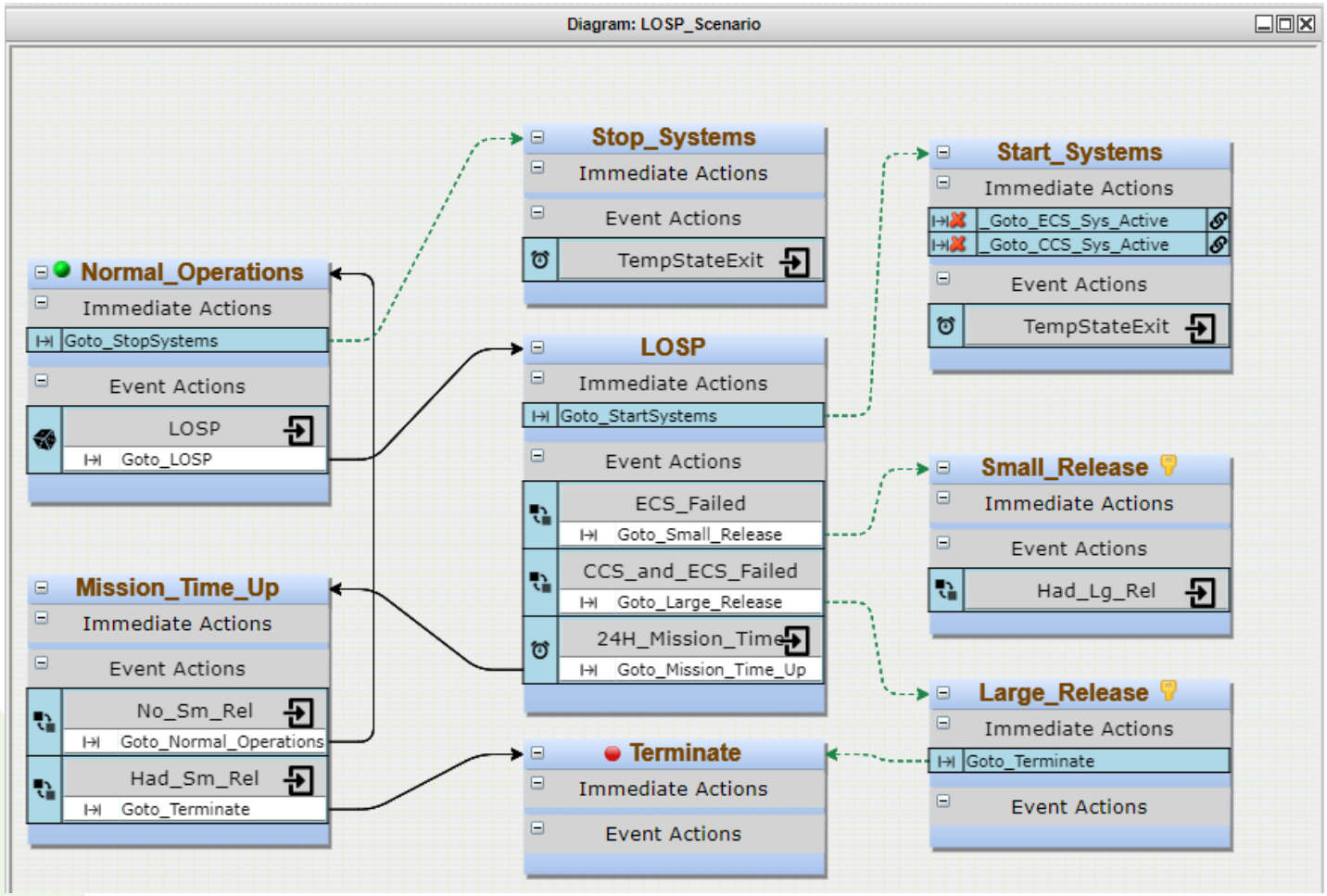
1. While there are states in the “New States” list, For each state:
   - Add the events to the “Time Events Queue” or “Conditional Events” list.
   - Execute any Immediate Actions

2. If any “Conditional Events” criteria is met.
   - Execute that events action/s.
   - Go to Step 1.

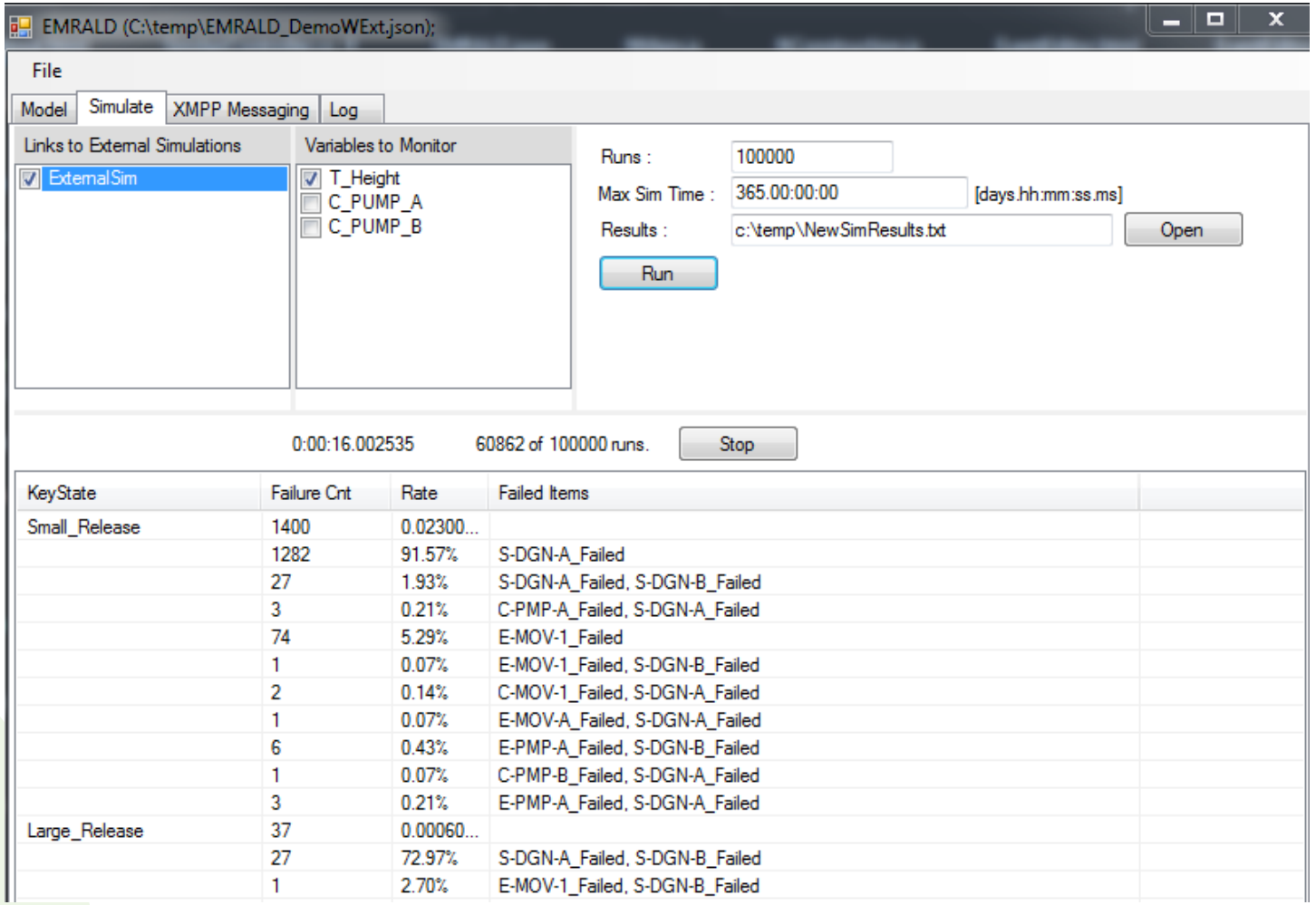
3. Jump to the next chronological event.
   - Process that event’s actions.
   - Go to Step 1.



Dynamic Framework

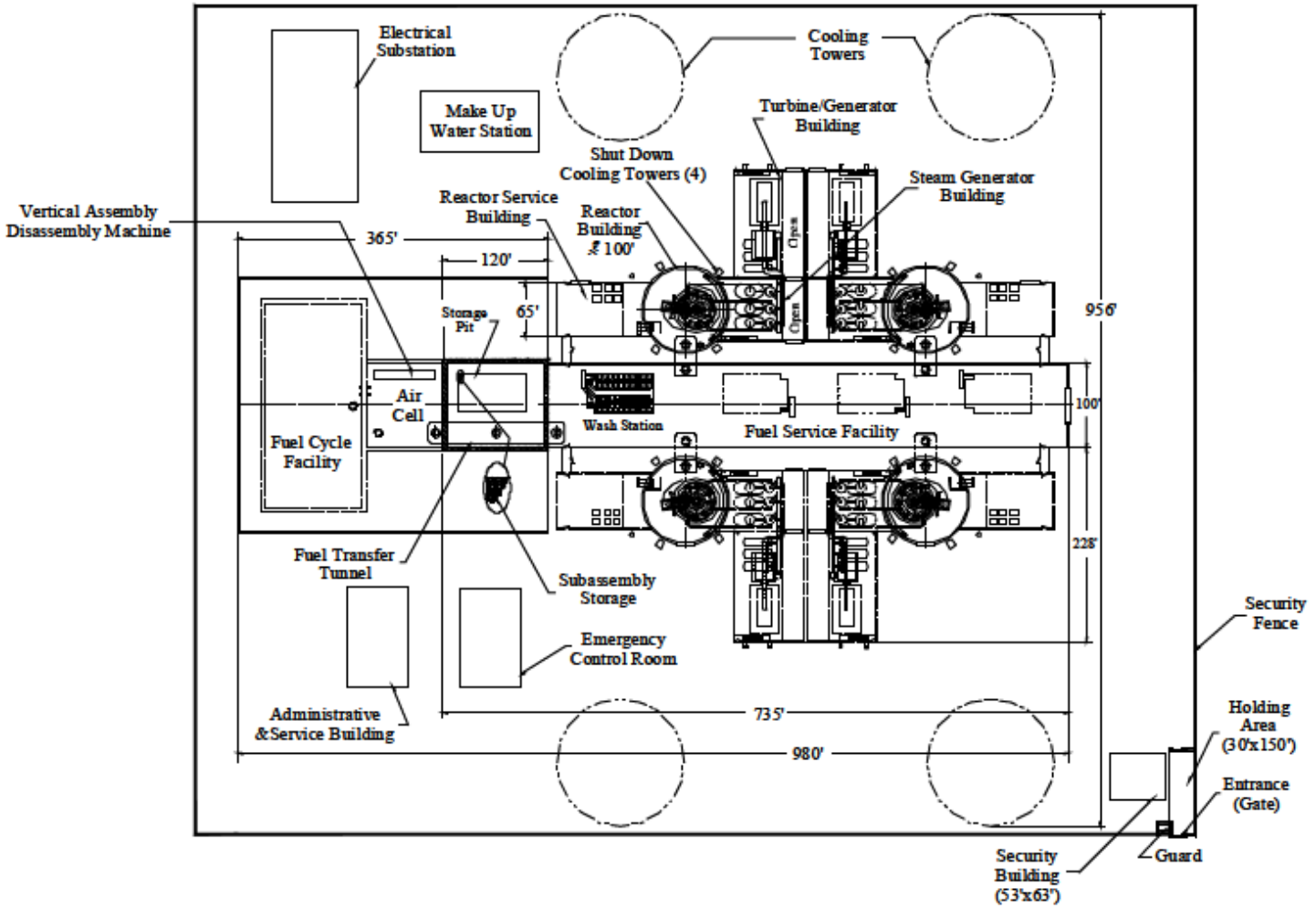


Dynamic Framework

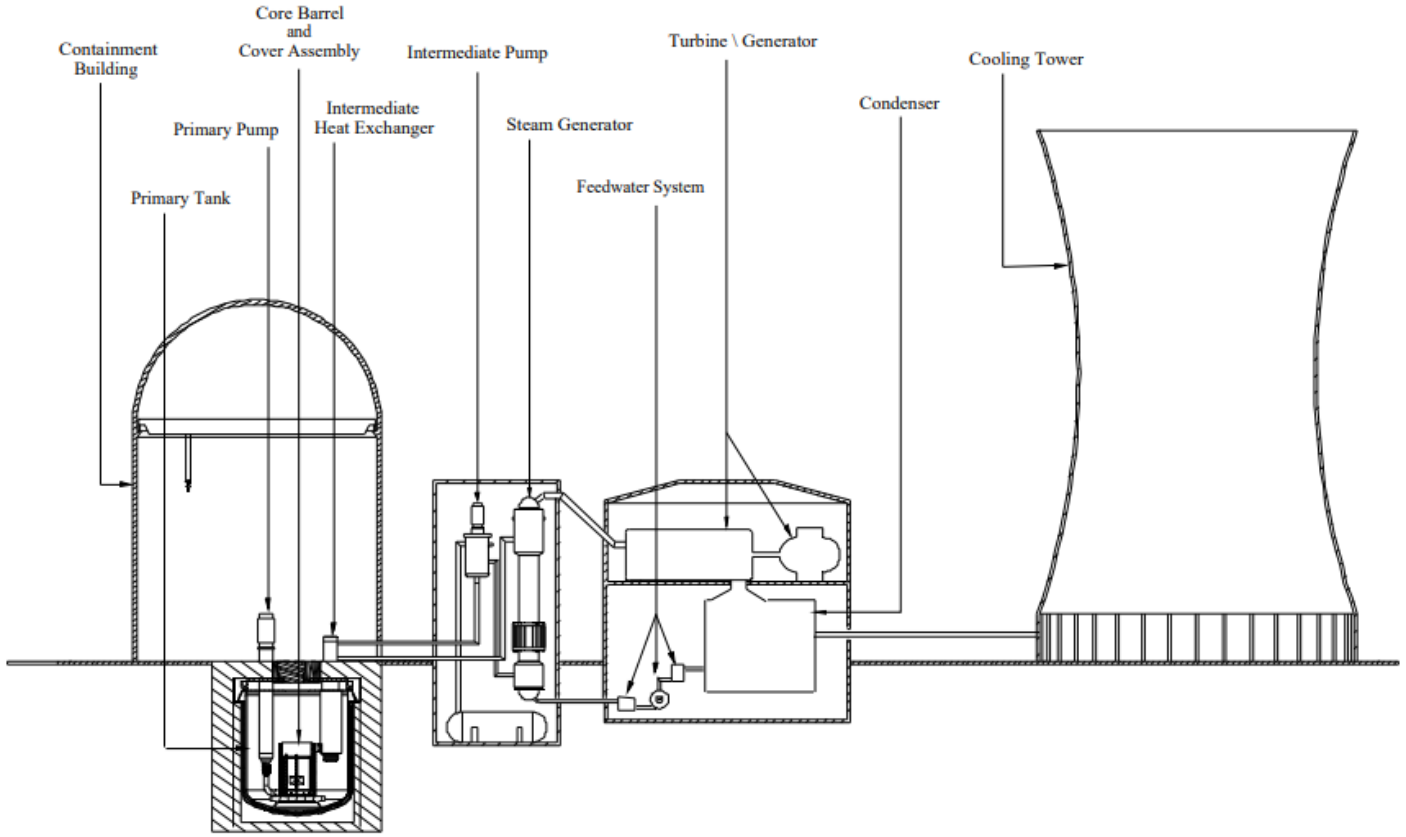


KeyState	Failure Cnt	Rate	Failed Items
Small_Release	1400	0.02300...	
	1282	91.57%	S-DGN-A_Failed
	27	1.93%	S-DGN-A_Failed, S-DGN-B_Failed
	3	0.21%	C-PMP-A_Failed, S-DGN-A_Failed
	74	5.29%	E-MOV-1_Failed
	1	0.07%	E-MOV-1_Failed, S-DGN-B_Failed
	2	0.14%	C-MOV-1_Failed, S-DGN-A_Failed
	1	0.07%	E-MOV-A_Failed, S-DGN-A_Failed
	6	0.43%	E-PMP-A_Failed, S-DGN-B_Failed
	1	0.07%	C-PMP-B_Failed, S-DGN-A_Failed
	3	0.21%	E-PMP-A_Failed, S-DGN-A_Failed
Large_Release	37	0.00060...	
	27	72.97%	S-DGN-A_Failed, S-DGN-B_Failed
	1	2.70%	E-MOV-1_Failed, S-DGN-B_Failed

Application of Dynamic Framework to SFR

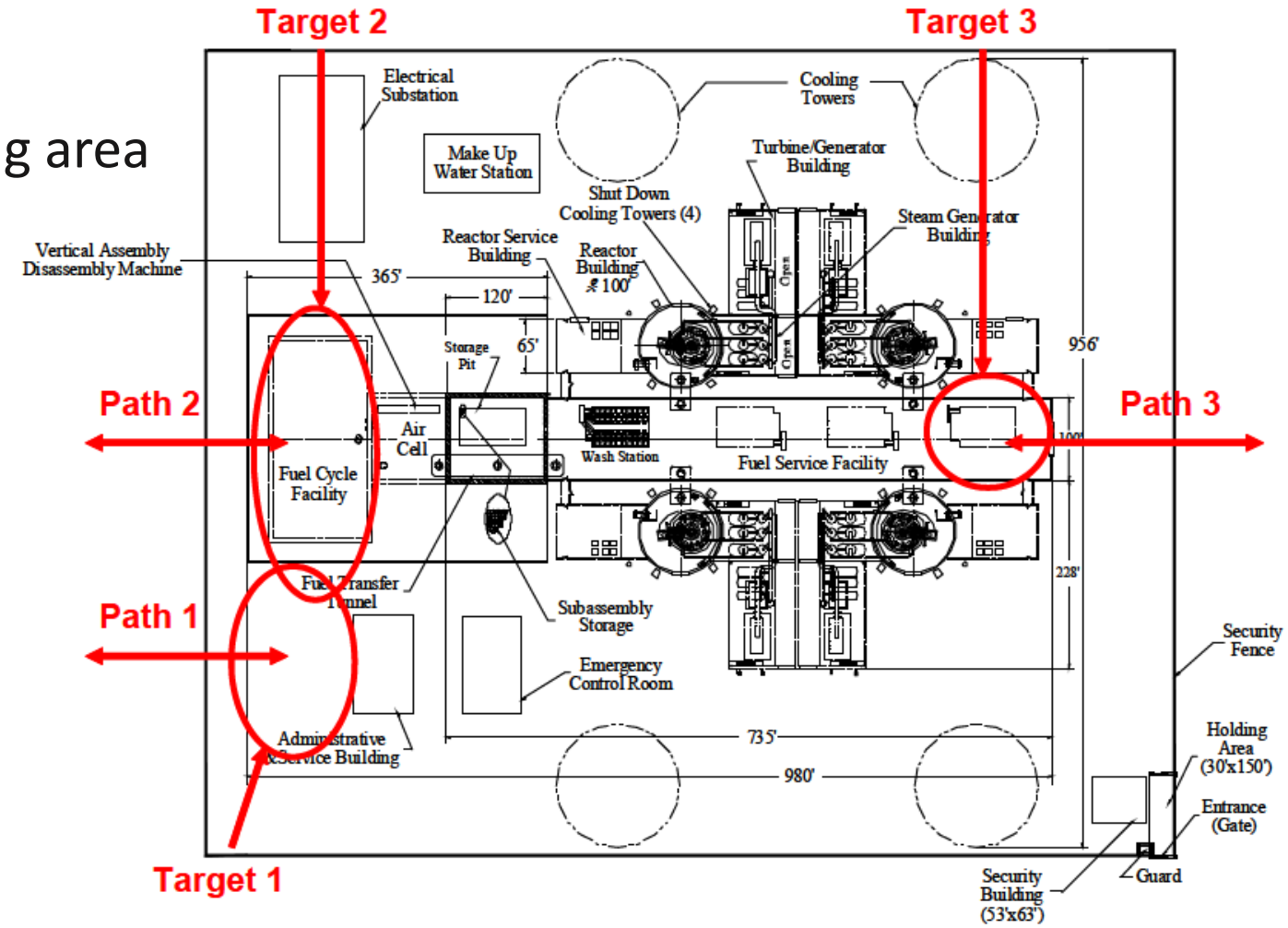


Application of Dynamic Framework to SFR



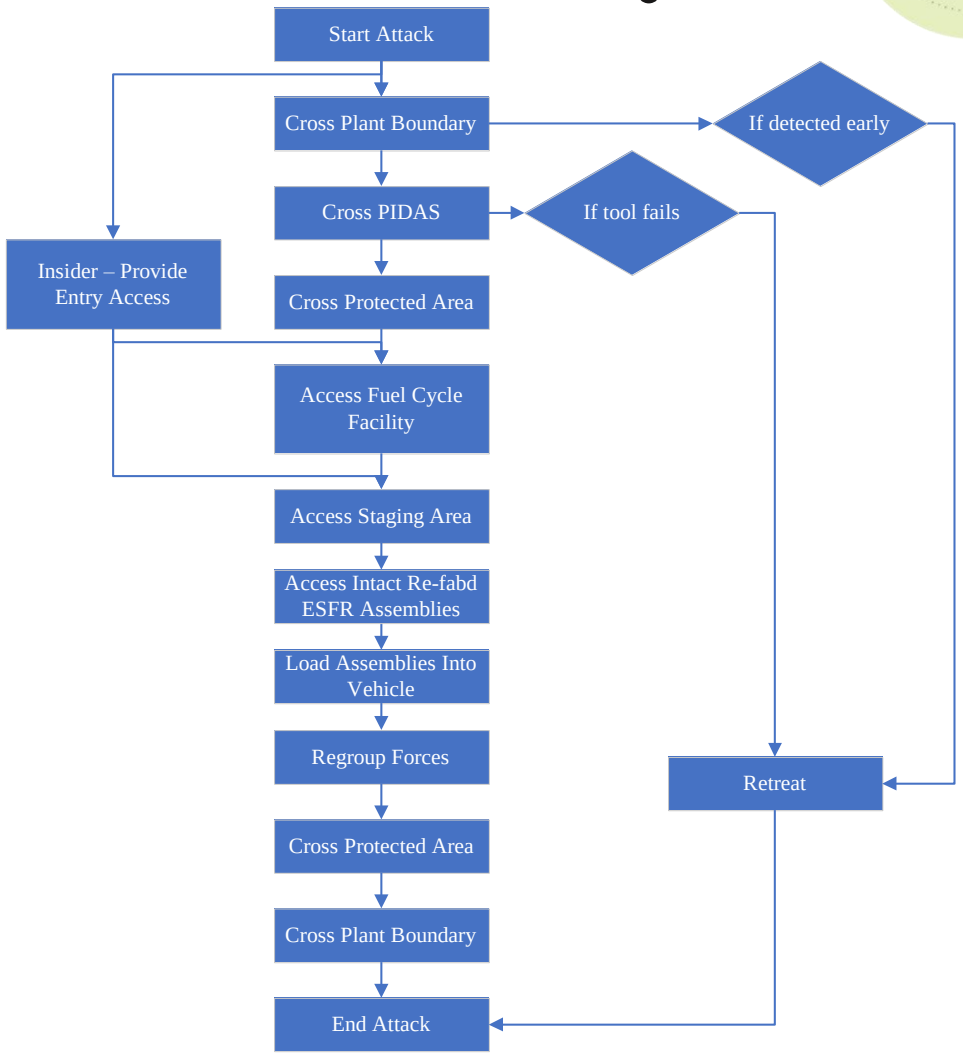
Theft Scenarios

- Targets:
  - LWR spent-fuel cask parking area
  - LWR spent-fuel storage
  - FCF
    - Air cell (hot cell)
    - Inert hot cell
  - Fuel services building staging/washing area

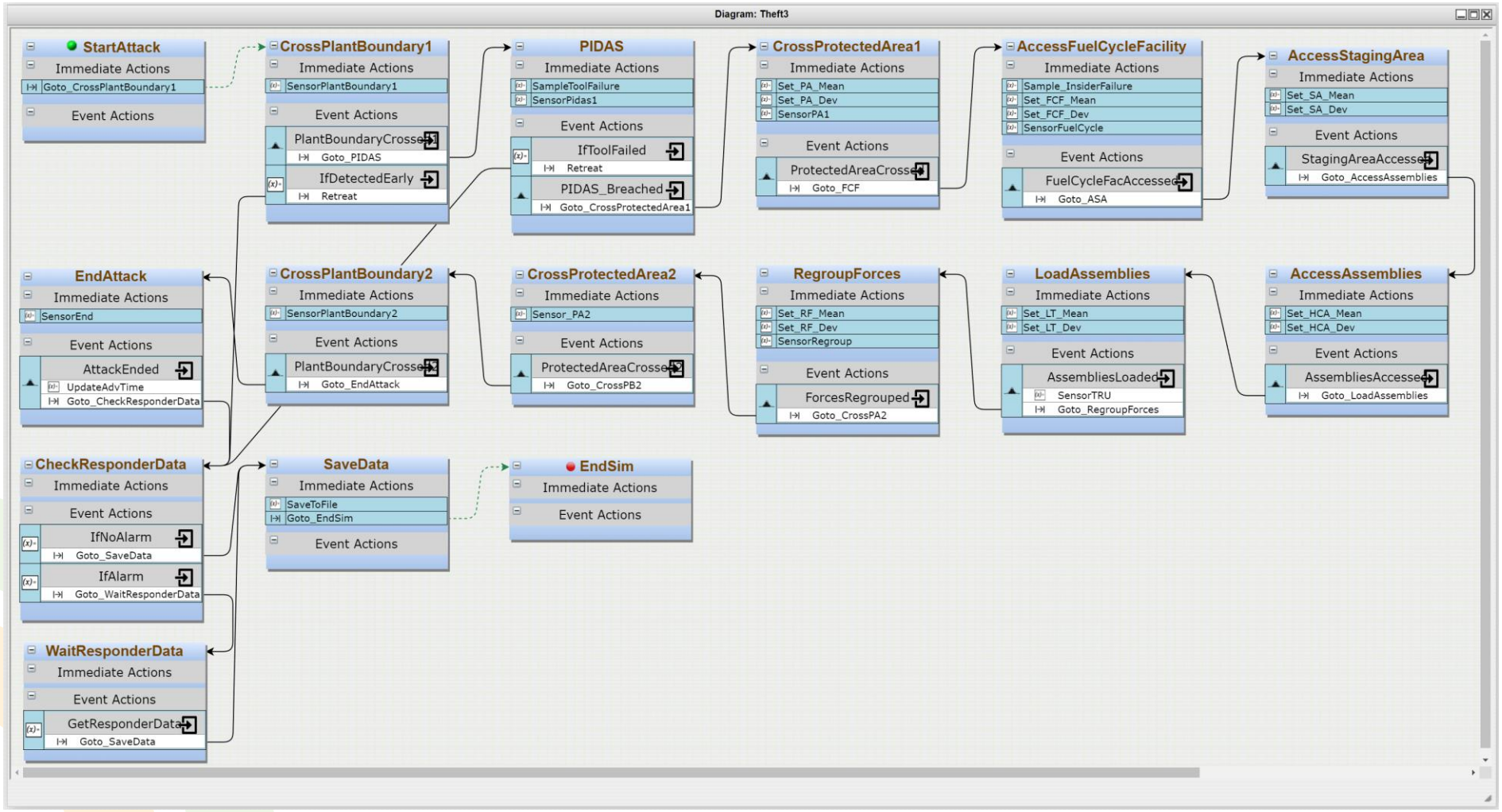


Theft Scenario 3

No.	Action	Detection probability	Mean delay time (seconds)	Std. deviation delay time (seconds)	Notes
1	Start attack	0	-	-	
2	Cross plant boundary	0.02	300	30	
3	Breach PIDAS	0.9	60	6	
4	Cross protected area	0.02	30	3	
5	Access fuel cycle facility	0.95	30	3	Insider assists by providing entry access
6	Access staging / washing area	0	300	30	
7	Access intact refabricated ESFR assemblies	0	90	9	
8	Load assemblies into vehicle				
9	Regroup forces	0	20	2	
10	Cross protected area	0	30	3	
11	Cross plant boundary	0	30	3	
12	End attack	0	30	3	

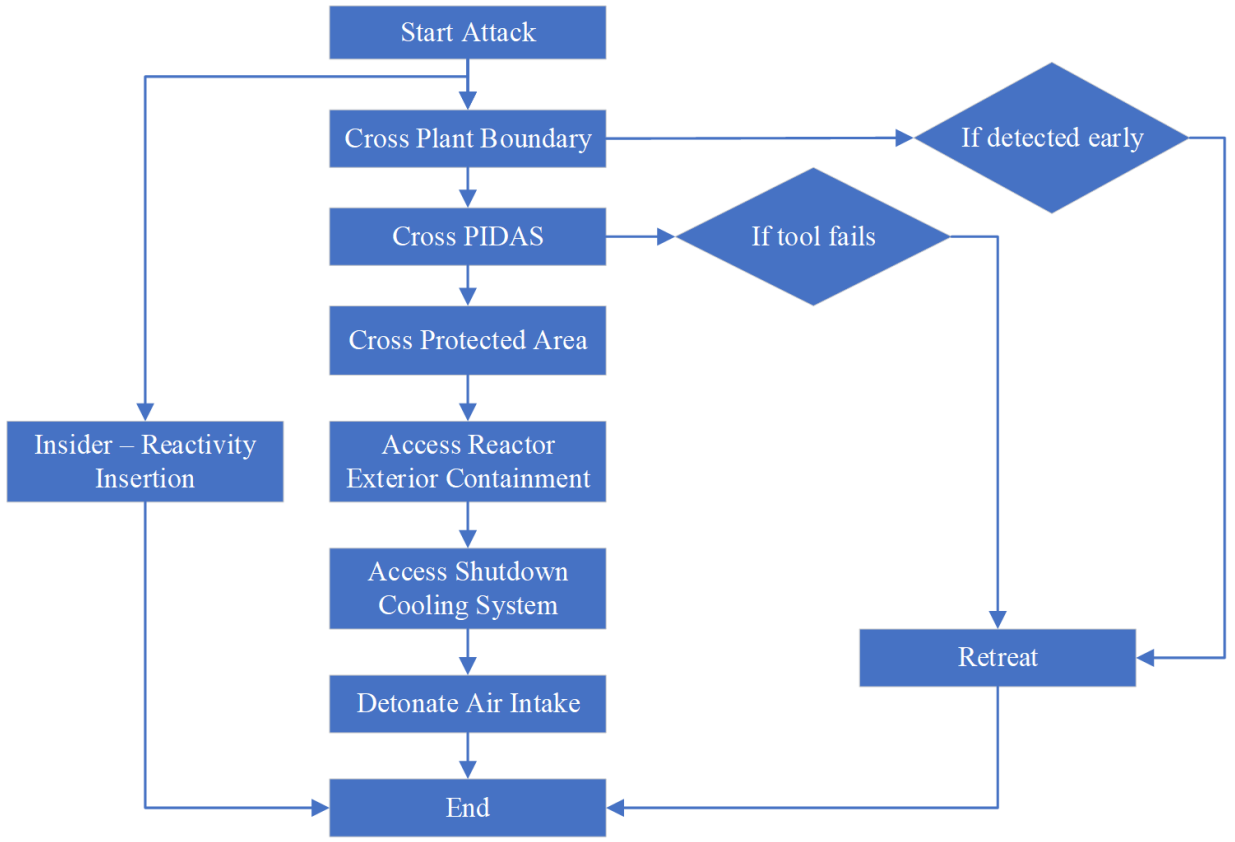


EMRALD model for Theft Scenario 3

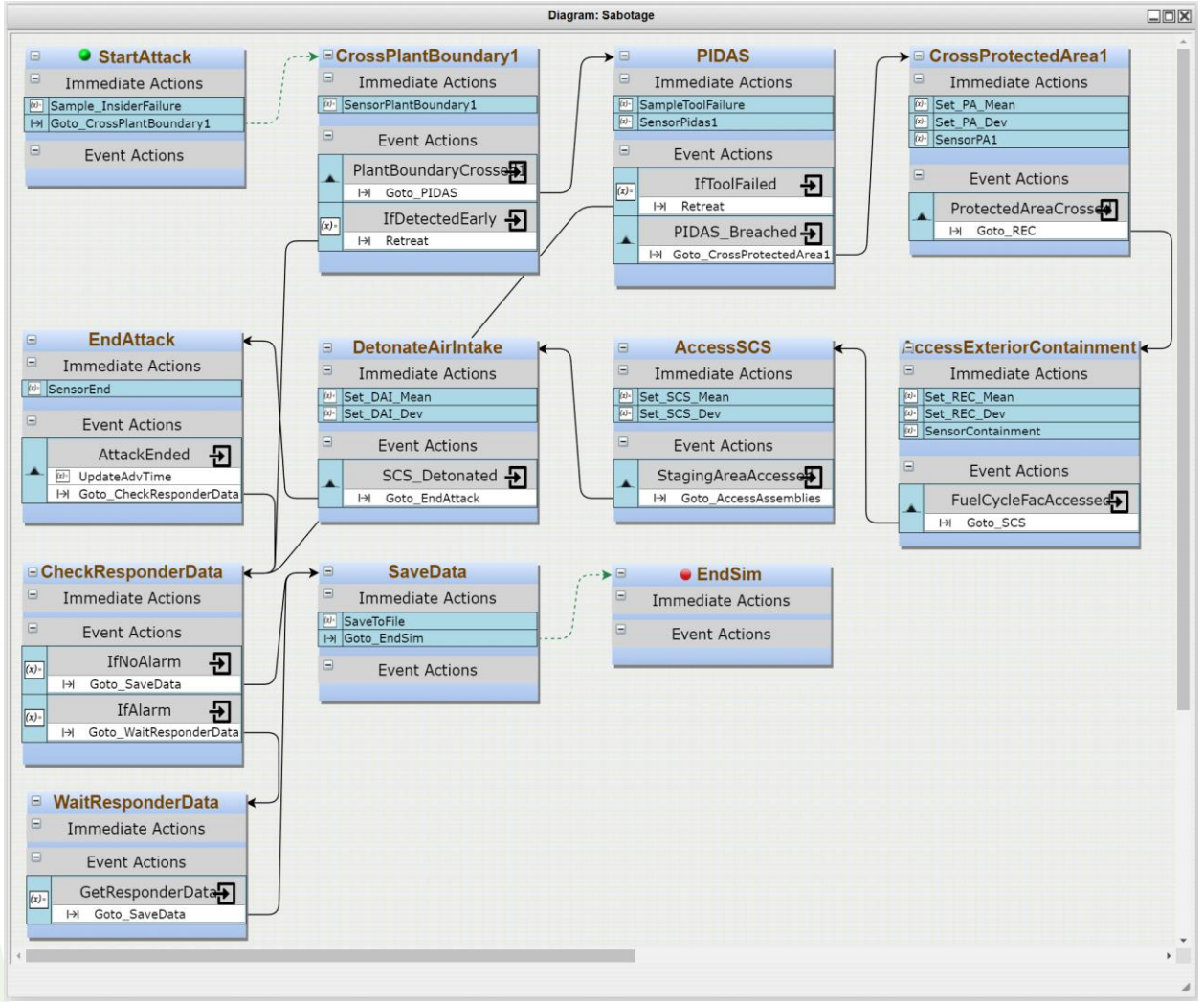


Sabotage Scenario

No.	Action	Detection probability	Mean delay time (seconds)	Std. deviation delay time (seconds)	Notes
1	Start attack	0	-	-	Insider inserts positive reactivity
2	Cross plant boundary	0.02	300	30	
3	Breach PIDAS	0.9	60	6	
4	Cross protected area	0.02	30	3	
5	Access reactor exterior containment	0.95	330	33	
6	Access shutdown cooling system	0	30	3	
7	Detonate Air Intake	0	1200	120	
8	End attack	0	0	0	



EMRALD model for Sabotage Scenario



Physical Protection System

- 3 armed-responder response times to give basic variations in protective strategy for probability of detection
- Simplified system, with limited detection capabilities

PPS	Mean response time (seconds)	Std. deviation of response time (seconds)
PPS A	150	15
PPS B	300	30
PPS C	600	60

EASI benchmark

Estimate of Adversary Sequence Interruption

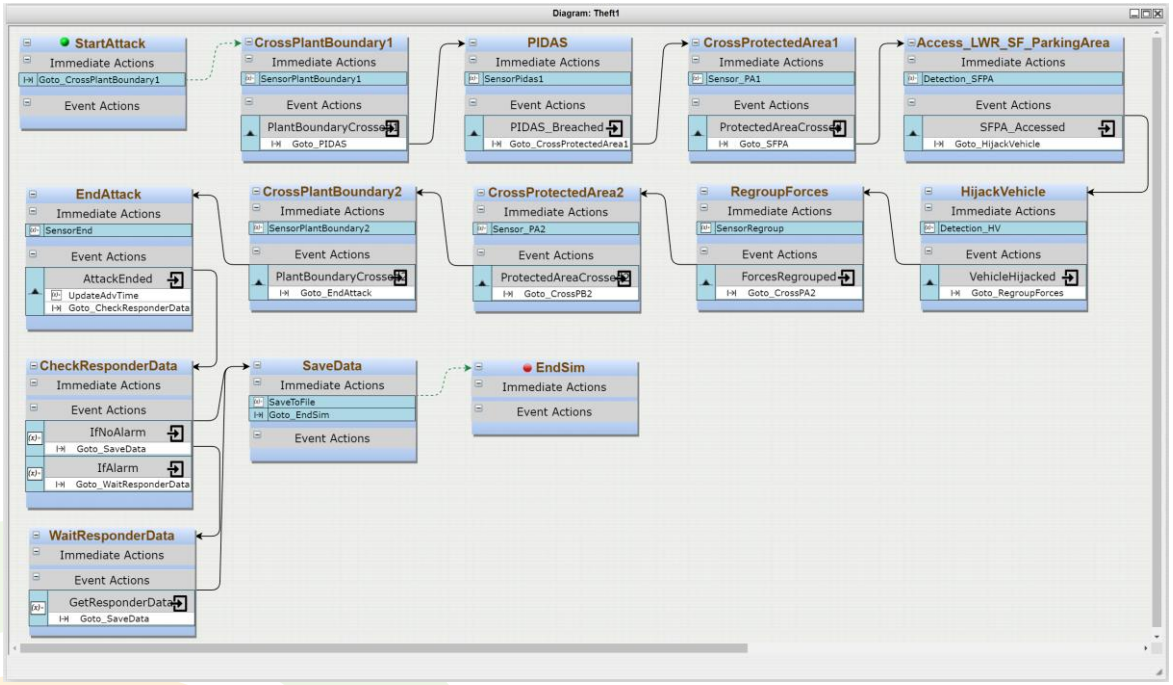
Probability of Guard Communication		Force Time (in Mean	Standard Deviation
1		300	30

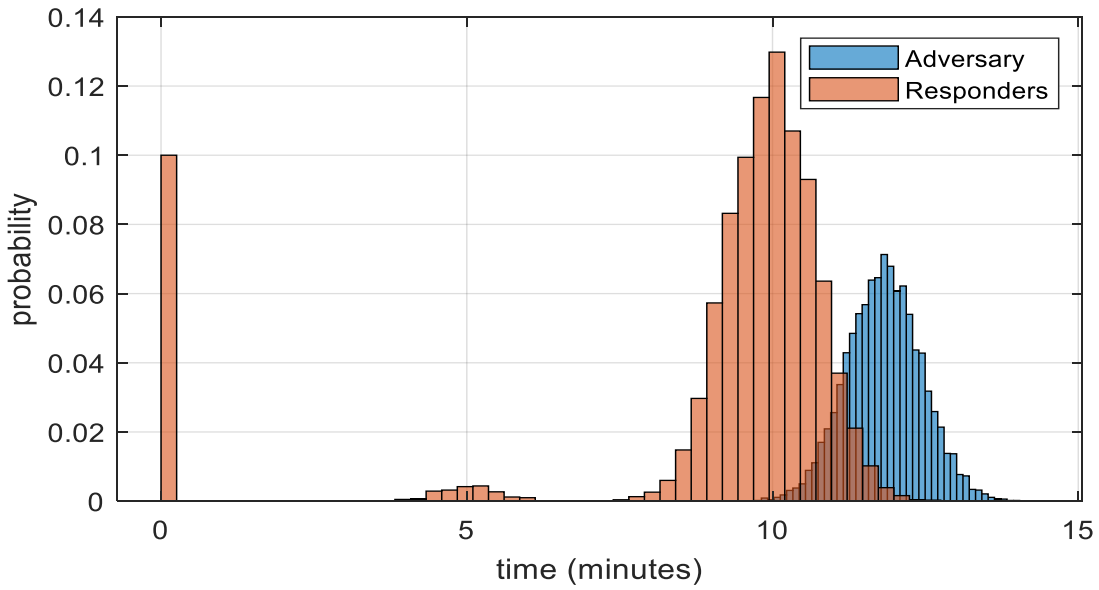
Theft of Spent Fuel Shipping Casks

Task	Description	P(Detection)	Location	Delays (in Seconds): Mean:	Standard Deviation	Rt	
1	Initiate Attack	0	M	0	0	710	
2	Cross Plant Boundary	0.02	M	300	30	710	
3	PIDAS	0.9	M	60	6	410	
4	Cross Protected Area	0.02	M	30	3	350	Critical Detection Point
5	Access LWR SF Parking Area	0.02	M	30	3	320	
6	Hijack Vehicle with LWR SF Cask	0.95	M	180	18	290	
7	Regroup Forces	0	M	20	2	110	
8	Cross Protected Area	0	M	30	3	90	
9	Cross Plant Boundary	0	M	30	3	60	
10	End Attack	0	M	30	3	30	
				710			

Probability of Interruption:	0.89

EMRALD benchmark

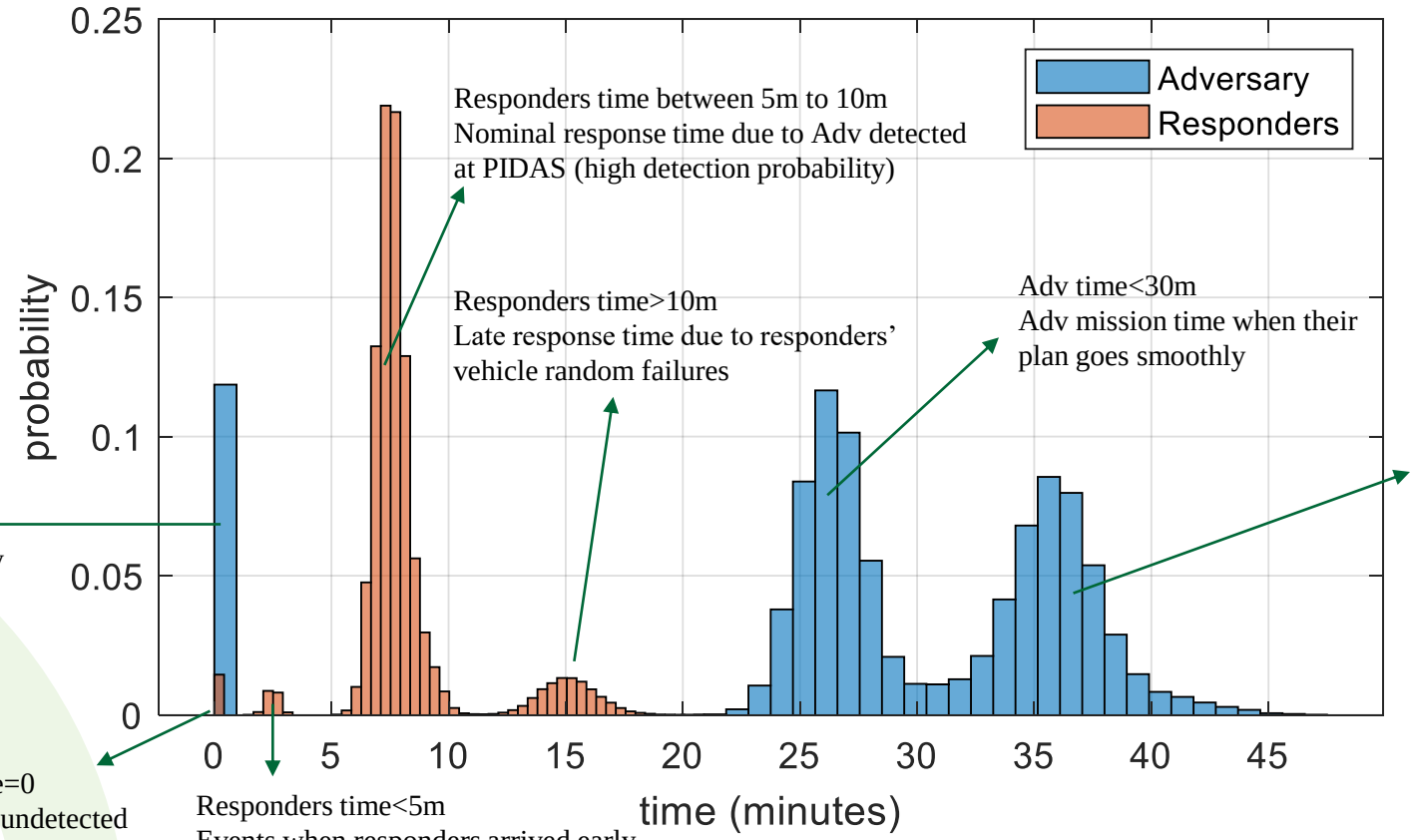




Results – Theft Scenario 3 – PPS A

<table>
<tr><td colspan="6">All attack cases: 100,000 times. $P_E = 0.50$</td></tr>
<tr><td colspan="2">Retreat: 11,867 times</td><td colspan="4">Continue attack as planned: 88,133 times</td></tr>
<tr><td>Undetected: 998 times</td><td>Early detection: 10,869 times</td><td rowspan="4">Undetected: 446 times</td><td colspan="3">Detected: 87,687 times</td></tr>
<tr><td colspan="3">Interrupted: 87,687 times</td></tr>
<tr><td colspan="2">Not neutralized: 49,215 times</td><td rowspan="2">Neutralized: 38,472 times</td></tr>
<tr><td colspan="2">Left facility and complete mission before shootout is over: 10,827 times</td><td>Adversaries neutralize responders: 38,388 times</td></tr>
</table>

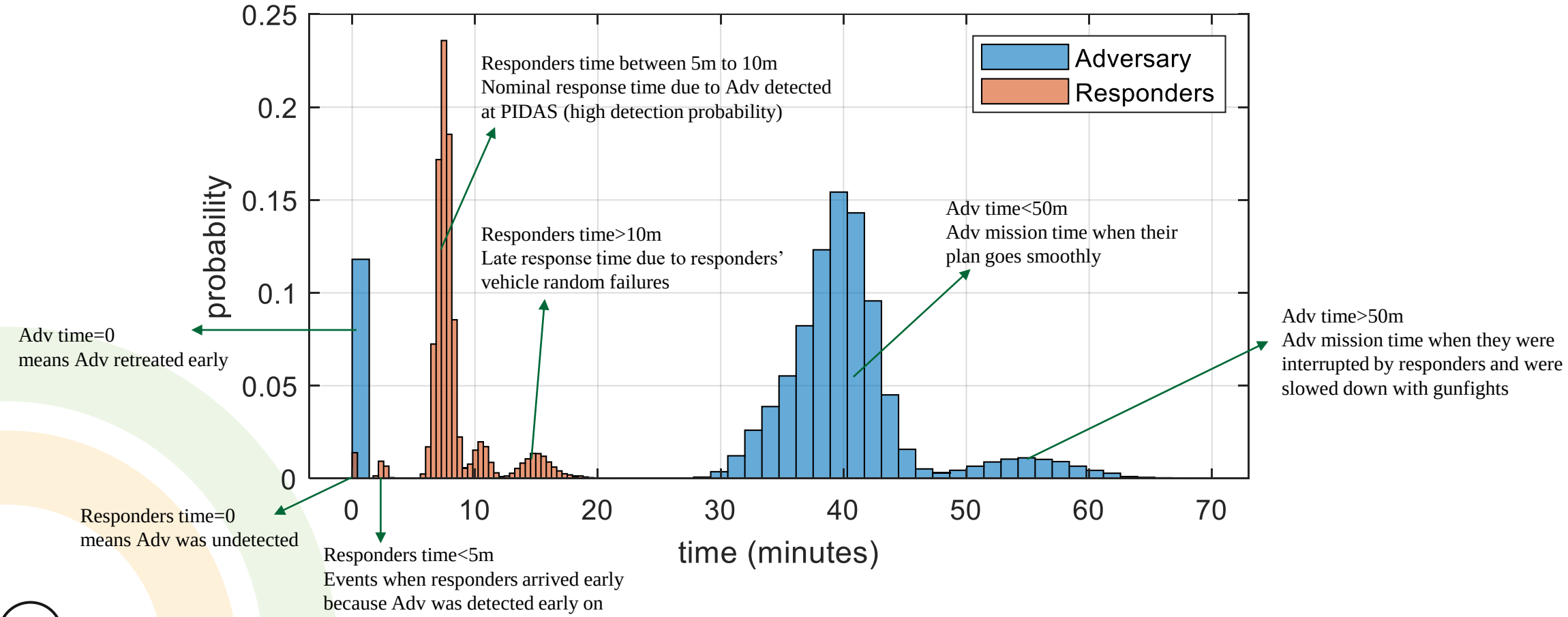
Results – Theft Scenario 3 – PPS A



Results – Sabotage – PPS A

<table>
<tr><td colspan="7">All attack cases: 100,000 times. $P_E = 0.75$</td></tr>
<tr><td colspan="2">Retreat: 11,799 times</td><td colspan="5">Continue attack as planned: 88,201 times</td></tr>
<tr><td rowspan="4">Undetected: 1,007 times</td><td rowspan="4">Early detection: 10,792 times</td><td rowspan="4">Undetected: 409 times</td><td colspan="4">Detected: 87,792 times</td></tr>
<tr><td rowspan="3">Uninterrupted: 0 times</td><td colspan="3">Interrupted: 87,792 times</td></tr>
<tr><td colspan="2">Not neutralized: 49,160 times</td><td rowspan="2">Neutralized: 38,632 times</td></tr>
<tr><td>Left facility and complete mission before shootout is over: 10,653 times</td><td>Adversaries neutralize responders: 38,507 times</td></tr>
</table>

Results – Sabotage – PPS A



Results – Comparison to EASI

Attack scenario	PPS	Static probability of interruption (P_I) calculated with EASI [20]	Dynamic probability of interruption (P_I) calculated with EMRALD	Probability of effectiveness (P_E) calculated with EMRALD
Theft target 1	A	**1**	**0.94**	0.34
	B	0.89	0.87	0.27
	C	**0.01**	**0.45**	0.18
Theft target 2	A	**1**	**0.90**	0.29
	B	0.46	0.85	0.13
	C	**0**	**0.01**	0.12
Theft target 3	A	0.99	0.99	0.50
	B	0.99	0.97	0.47
	C	**0.99**	**0.89**	0.43
Sabotage	A	**1**	**~1**	0.75
	B	1	0.99	0.75
	C	1	0.90	0.72

Summary

- Current physical protection evaluation method is static and conservative. The dynamic modeling method using INL's EMRALD may reduce PPS design conservatism and cost.
- EMRALD based consequence-based security analysis can be leveraged for designing optimum security posture of advanced reactors.
- Consequence and timeline-based security could pave way for exploring the concepts of security-by-design, crediting operator actions, and off-site response.

Thank you

Report: https://www.osti.gov/biblio/1959000

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